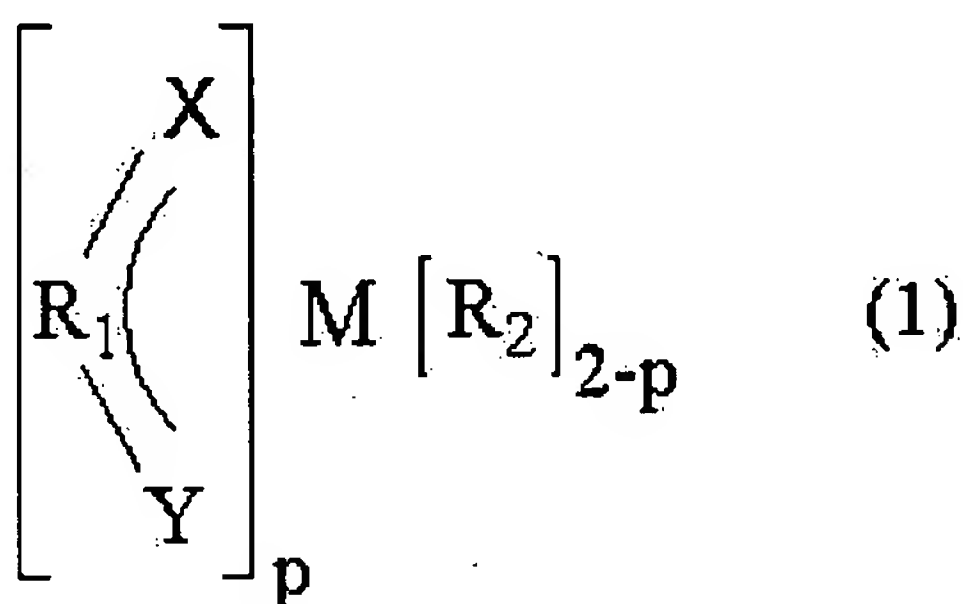


What is claimed is:

1. A catalytic system of producing cyclic olefin polymers having polar functional groups by polymerizing cyclic olefin monomers having polar functional groups, wherein the catalytic system includes:

- 5 i) a procatalyst represented by formula (1) containing a Group 10 metal, having a ligand containing a heteroatom which is directly coordinated to the metal; and
ii) a cocatalyst represented by formula (2), including a salt compound which comprises a phosphonium group:

Formula 1



wherein X and Y are each independently a heteroatom selected from S, O, and N, or

said heteroatom is additionally linked to a moiety selected from hydrogen; a
15 linear or branched C₁₋₂₀ alkyl, alkenyl or vinyl; a C₅₋₁₂ cycloalkyl substituted or unsubstituted with a hydrocarbon; a C₆₋₄₀ aryl substituted or unsubstituted with a hydrocarbon; a C₇₋₁₅ aralkyl substituted or unsubstituted with a hydrocarbon; and a C₃₋₂₀ alkynyl;

R₁ and R₂ are each independently a linear or branched C₁₋₂₀ alkyl, alkenyl or
20 vinyl; a C₅₋₁₂ cycloalkyl substituted or unsubstituted with a hydrocarbon; a C₆₋₄₀ aryl substituted or unsubstituted with a hydrocarbon; a C₇₋₁₅ aralkyl substituted or unsubstituted with a hydrocarbon; or a C₃₋₂₀ alkynyl;

M is a Group 10 metal; and

p is from 0 to 2; and

Formula 2



wherein a, b, and c each are an integer of 0 to 3, and $a+b+c=3$;

5 Z is oxygen, sulfur, silicon, or nitrogen;

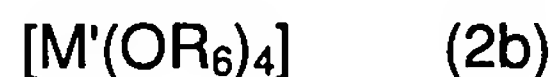
d is 1 when Z is oxygen or sulfur, 2 when Z is nitrogen, or 3 when Z is silicon;

R_3 is a hydrogen, an alkyl, or an aryl;

each of R_4 , R_4' and R_5 is independently a hydrogen; a linear or branched C_{1-20} alkyl, alkoxy, allyl, alkenyl or vinyl; a C_{3-12} cycloalkyl optionally substituted by a hydrocarbon; a C_{6-40} aryl optionally substituted by a hydrocarbon; a C_{7-15} aralkyl optionally substituted by a hydrocarbon; a C_{3-20} alkynyl; a tri(linear or branched C_{1-10} alkyl)silyl; a tri(linear or branched C_{1-10} alkoxy)silyl; a tri(optionally substituted C_{3-12} cycloalkyl)silyl; a tri(optionally substituted C_{6-40} aryl)silyl; a tri(optionally substituted C_{6-40} aryloxy)silyl; a tri(linear or branched C_{1-10} alkyl)siloxy; a tri(optionally substituted C_{3-12} cycloalkyl)siloxy; or a tri(optionally substituted C_{6-40} aryl)siloxy, and wherein the substituent is a halogen or C_{1-20} haloalkyl; and

[Ani] is an anion capable of weakly coordinating to the metal M of the procatalyst and is selected from the group consisting of borates, aluminates, $[SbF_6]^-$, $[PF_6]^-$, $[AsF_6]^-$, perfluoroacetate ($[CF_3CO_2]^-$), perfluoropropionate ($[C_2F_5CO_2]^-$), perfluorobutyrate ($[CF_3CF_2CF_2CO_2]^-$), perchlorate ($[ClO_4]^-$), p-toluenesulfonate ($[p-CH_3C_6H_4SO_3]^-$), $[SO_3CF_3]^-$, boratabenzenes, and carboranes optionally substituted with a halogen.

2. The catalytic system of claim 1, wherein the borate or aluminate of formula (2) is an anion represented by formula (2a) or (2b):

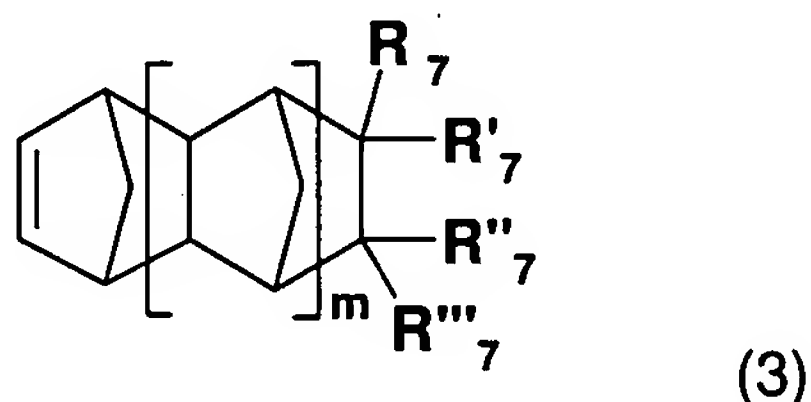


where M' is B or Al;

R_6 is each independently a halogen, a linear or branched C_{1-20} alkyl or alkenyl optionally substituted by a halogen, a C_{3-12} cycloalkyl optionally substituted by a halogen,

a C₆₋₄₀ aryl optionally substituted by a hydrocarbon, a C₆₋₄₀ aryl optionally substituted by a linear or branched C₃₋₂₀ trialkylsiloxy or a linear or branched C₁₈₋₄₈ triarylsiloxy, or a C₇₋₁₅ aralkyl optionally substituted by a halogen.

- 5 3. The catalytic system of claim 1, wherein the cyclic olefin monomer having a polar functional group polymerized by the catalytic system is a compound represented by formula (3):



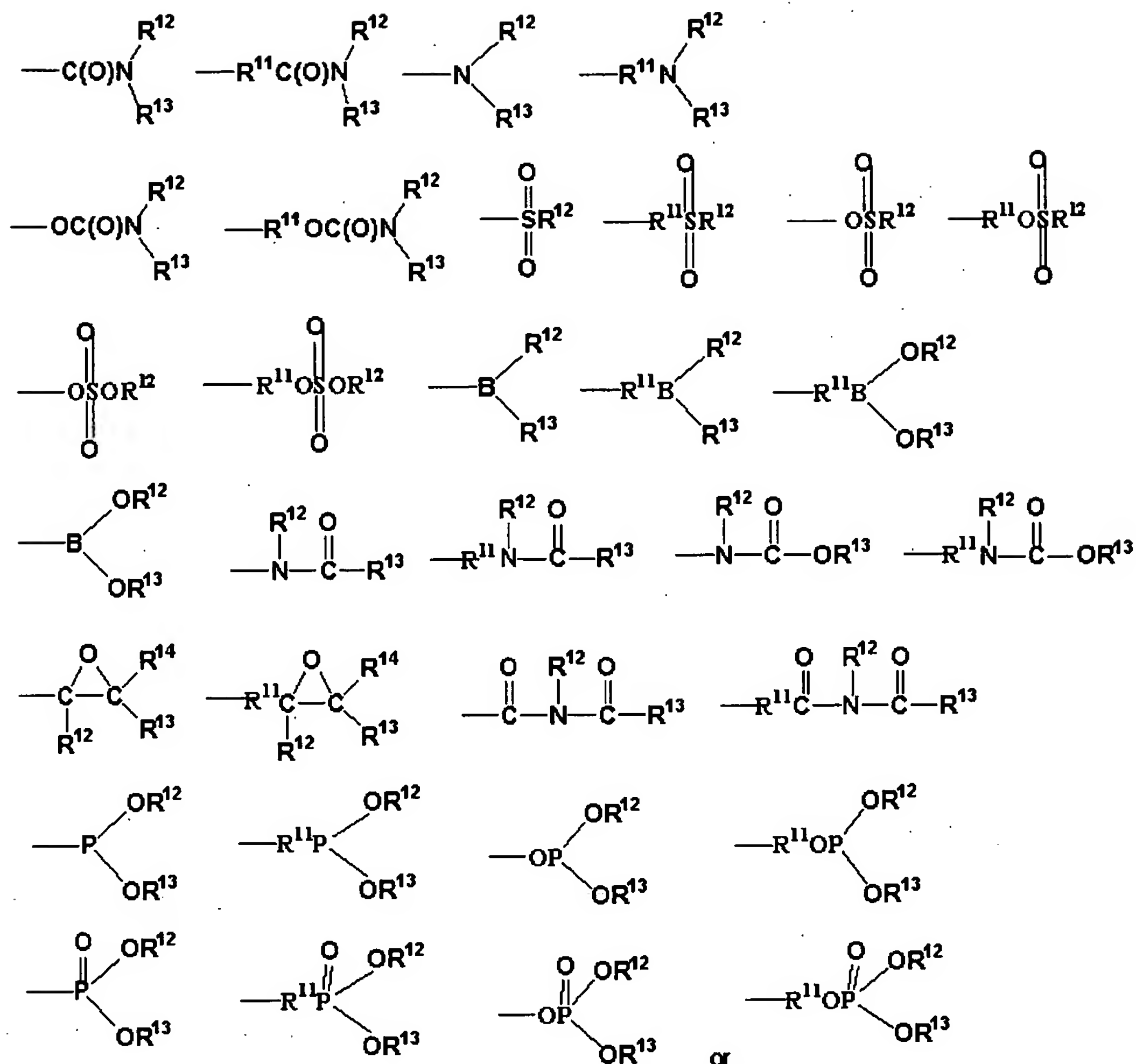
where m is an integer from 0 to 4;

- 10 at least one of R₇, R'₇, R''₇ and R'''₇ is a polar functional group and the others are nonpolar functional groups;

R₇, R'₇, R''₇ and R'''₇ can be bonded together to form a saturated or unsaturated C₄₋₁₂ cyclic group or a C₆₋₂₄ aromatic ring;

- 15 the nonpolar functional group is a hydrogen; a halogen; a linear or branched C₁₋₂₀ alkyl, haloalkyl, alkenyl or haloalkenyl; a linear or branched C₃₋₂₀ alkynyl or haloalkynyl; a C₃₋₁₂ cycloalkyl optionally substituted by an alkyl, an alkenyl, an alkynyl, a halogen, a haloalkyl, a haloalkenyl or haloalkynyl; a C₆₋₄₀ aryl optionally substituted by an alkyl, an alkenyl, an alkynyl, a halogen, a haloalkyl, a haloalkenyl or haloalkynyl; or a C₇₋₁₅ aralkyl optionally substituted by an alkyl, an alkenyl, an alkynyl, a halogen, a haloalkyl, a haloalkenyl or haloalkynyl;
- 20 the polar functional group is a non-hydrocarbonaceous polar group having at least one O, N, P, S, Si or B and is

- least one O, N, P, S, Si or B and is -R⁸OR⁹, -OR⁹, -OC(O)OR⁹, -R⁸OC(O)OR⁹, -C(O)R⁹, -R⁸C(O)OR⁹, -C(O)OR⁹, -R⁸C(O)R⁹, -OC(O)R⁹, -R⁸OC(O)R⁹, -(R⁸O)_k-OR⁹, -(OR⁸)_k-OR⁹, -C(O)-O-C(O)R⁹, -R⁸C(O)-O-C(O)R⁹, -SR⁹, -R⁸SR⁹, -SSR⁸, -R⁸SSR⁹, -S(=O)R⁹, -R⁸S(=O)R⁹, -R⁸C(=S)R⁹, -R⁸C(=S)SR⁹, -R⁸SO₃R⁹, -SO₃R⁹, -R⁸N=C=S, -NCO, R⁸-NCO, -CN, -R⁸CN, -NNC(=S)R⁹, -R⁸NNC(=S)R⁹, -NO₂, -R⁸NO₂,
- 25



wherein each of R^8 is a linear or branched C_{1-20} alkylene, haloalkylene, alkenylene or haloalkenylene; a linear or branched C_{3-20} alkynylene or haloalkynylene; a C_{3-12} cycloalkylene optionally substituted by an alkyl, an alkenyl, an alkynyl, a halogen, a haloalkyl, a haloalkenyl or haloalkynyl; a C_{6-40} arylene optionally substituted by an alkyl, an alkenyl, an alkynyl, a halogen, a haloalkyl, a haloalkenyl or haloalkynyl; or a C_{7-15} aralkylene optionally substituted by an alkyl, an alkenyl, an alkynyl, a halogen, a haloalkyl, a haloalkenyl or haloalkynyl;

each of R^9 , R^{10} , R^{12} and R^{13} is a hydrogen; a halogen; a linear or branched C_{1-20} alkyl, haloalkyl, alkenyl or haloalkenyl; a linear or branched C_{3-20} alkynyl or haloalkynyl; a C_{3-12} cycloalkyl optionally substituted by an alkyl, an alkenyl, an alkynyl, a halogen, a

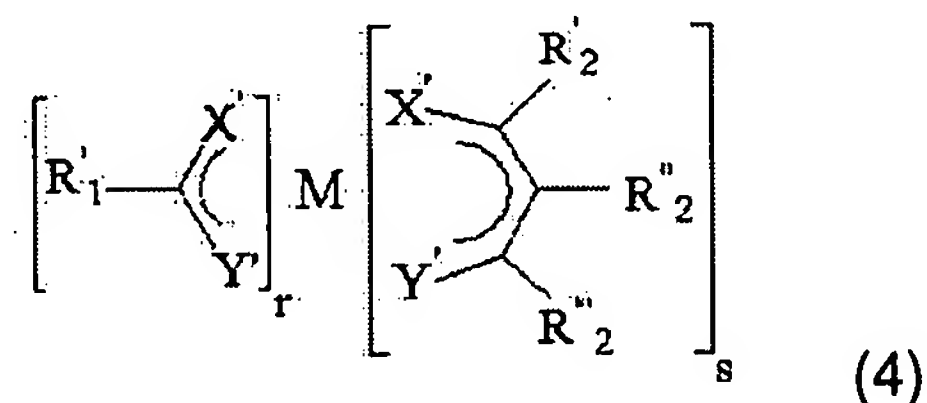
haloalkyl, a haloalkenyl or haloalkynyl; a C₆₋₄₀ aryl optionally substituted by an alkyl, an alkenyl, an alkynyl, a halogen, a haloalkyl, a haloalkenyl or haloalkynyl; a C₇₋₁₅ aralkyl optionally substituted by an alkyl, an alkenyl, an alkynyl, a halogen, a haloalkyl, a haloalkenyl or haloalkynyl; or an alkoxy, an haloalkoxy, a carbonyloxy or a halocarbonyloxy; and

k is an integer from 1 to 10.

4. The catalytic system of claim 1, wherein the i) procatalyst and ii) cocatalyst are respectively,

i) a procatalyst represented by formula (4) containing a Group 10 metal, having a ligand containing a heteroatom which is directly coordinated to the metal; and

ii) a cocatalyst represented by formula (5), including a salt compound which comprises a phosphonium group;



where each of X' and Y' is a heteroatom selected from S and O;

each of R₁', R₂', R₂' and R₂' is a linear or branched C₁₋₂₀ alkyl, alkenyl or vinyl; a C₅₋₁₂ cycloalkyl optionally substituted by a hydrocarbon; a C₆₋₄₀ aryl optionally substituted by a hydrocarbon; a C₇₋₁₅ aralkyl optionally substituted by a hydrocarbon; or a C₃₋₂₀ alkynyl;

M is a Group 10 metal; and

each of r and s is an integer from 0 to 2 and r+s = 2, and



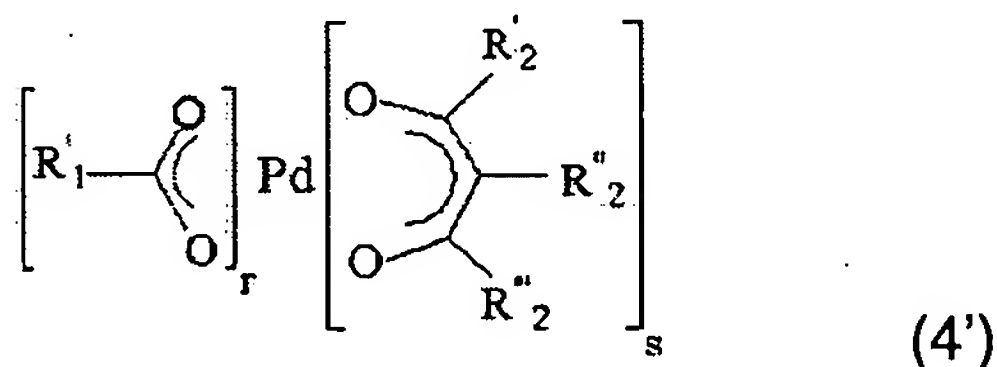
where R₄ is a hydrogen; a linear or branched C₁₋₂₀ alkyl, alkoxy, allyl, alkenyl or vinyl; an optionally substituted C₃₋₁₂ cycloalkyl; an optionally substituted C₆₋₄₀ aryl; an optionally substituted C₇₋₁₅ aralkyl; or a C₃₋₂₀ alkynyl, in which each substituent is a halogen or a C₁₋₂₀ haloalkyl; and

[Ani] is an anion capable of weakly coordinating to the metal M of the procatalyst represented by formula (1) and is selected from the group consisting of borates, aluminates, $[\text{SbF}_6]^-$, $[\text{PF}_6]^-$, $[\text{AsF}_6]^-$, perfluoroacetate ($[\text{CF}_3\text{CO}_2]^-$), perfluoropropionate ($[\text{C}_2\text{F}_5\text{CO}_2]^-$), perfluorobutyrate ($[\text{CF}_3\text{CF}_2\text{CF}_2\text{CO}_2]^-$), perchlorate ($[\text{ClO}_4]^-$), p-toluenesulfonate ($[\text{p-CH}_3\text{C}_6\text{H}_4\text{SO}_3]^-$), $[\text{SO}_3\text{CF}_3]^-$, boratabenzenes, and carboranes optionally substituted by a halogen.

5. The catalytic system of claim 4, wherein the i) procatalyst and ii) cocatalyst are respectively,

i) a procatalyst represented by formula (4') containing Pd, having a ligand containing O atom which is directly coordinated to the metal; and

ii) a cocatalyst represented by formula (5), including a salt compound which comprises a phosphonium group;



where each of R_1' , R_2' , R_2'' and R_2''' is a linear or branched C_{1-20} alkyl, alkenyl or vinyl; a C_{5-12} cycloalkyl optionally substituted by a hydrocarbon; a C_{6-40} aryl optionally substituted by a hydrocarbon; a C_{7-15} aralkyl optionally substituted by a hydrocarbon; or a C_{3-20} alkynyl; and

each of r and s is an integer from 0 to 2 and $r+s = 2$.

6. The catalytic system of claim 5, wherein the i) procatalyst and ii) cocatalyst are, respectively,

i) a procatalyst represented by formula (4') containing Pd, wherein the heteroatom-containing ligand which is directly coordinated to the metal is acetylacetonate or acetate; and

ii) a cocatalyst represented by formula (5), including a salt compound which comprises a phosphonium group, wherein R₄ is cyclohexyl, butyl, or phenyl .

7. A method of producing cyclic olefin polymers having polar functional groups, which comprises:

preparing a catalytic system comprising the procatalyst and cocatalyst of any one of claims 1, 4, 5, and 6; and

performing addition-polymerization by contacting the catalyst mixture with an organic solution containing the monomer of claim 3, at a temperature of 80-150° C to obtain an addition polymer.

8. The method of claim 7, wherein the ratio of the cocatalyst to the procatalyst containing a Group 10 transition metal is in the range of 0.5 to 10 moles based on 1 mole of the procatalyst.

9. The method of claim 7, wherein the catalyst mixture is supported on a micro particle support.

10. The method of claim 9, wherein the inorganic support is at least one selected from the group consisting of silica, titania, silica/chromia, silica/chromia/titania, silica/alumina, aluminum phosphate gel, silanized silica, silica hydrogel, montmorillonite clay and zeolite.

11. The method of claim 7, wherein the organic solvent used to dissolve the catalyst mixture is at least one solvent selected from the group consisting of dichloromethane, dichloroethane, toluene, chlorobenzene and a mixture thereof.

12. The method of claim 7, wherein the total amount of the organic solvent is 50-800% based on the weight of the total monomer in the monomer solution.

13. The method of any one of claims 1, 4, 5, and 6, wherein the catalyst
5 mixture comprises a metal catalyst complex composed of the procatalyst and the cocatalyst.

14. The method of claim 7, wherein the catalyst mixture is added in a solid phase to the monomer solution.

10

15. The method of claim 7, wherein the catalyst mixture is added to the reaction mixture in an amount such that the molar ratio of the procatalyst to the total monomer in said monomer solution is 1:2,500 to 1:200,000.

15

16. The method of claim 7, wherein the monomer solution further comprises a cyclic olefin compound having no polar functional group.

20

17. The method of claim 7, wherein the cyclic olefin polymers having polar functional groups comprise a cyclic olefin homopolymer, a copolymer of cyclic olefin monomers having different polar functional groups, or a copolymer of a cyclic olefin monomer having a polar functional group with a cyclic olefin monomer having no polar functional group.

25

18. The method of claim 7, wherein the weight average molecular weight M_w of the cyclic olefin polymer having a polar functional group is 100,000-1,000,000.

19. A cyclic olefin polymer having a polar functional group having a weight average molecular weight M_w of 100,000 or more prepared using the method of any one of claims 7 to 18.

20. An optical anisotropic film comprising a cyclic olefin polymer having a polar functional group having a weight average molecular weight M_w of 100,000 or more prepared using the method of any one of claims 7 to 18.

5

21. The optical anisotropic film of claim 20, which has a retardation value R_{th} represented by Equation (4) of 70-1000 nm:

$$R_{th} = \Delta(n_y - n_z) \times d \quad (1)$$

where n_y is the refractive index of an in-plane fast axis measured at 550 nm;

10 n_z is the refractive index in a direction through the film thickness measured at 550 nm, and

d is the film thickness.

22. The optical anisotropic film of claim 20, which is a negative C-plate type
15 optical compensation film for liquid crystal display, satisfying a refractive index requirement of $n_x \cong n_y < n_z$, in which n_x is the refractive index of an in-plane slow axis, n_y is a refractive index of an in-plane fast axis, and n_z is the refractive index in a direction through the film thickness.